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Role of Assessment of The Diaphragm by Ultrasound During Weaning from Mechanical Ventilation in Patients with Chronic Obstructive Pulmonary Disease

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ABSTRACT

Background: Diaphragmatic Rapid Shallow Breathing Index (D-RSBI) is a new promising tool to predict weaning outcome. The D-RSB), which is the ratio between respiratory rate (RR) and the ultrasonographic evaluation of diaphragmatic displacement. Its accuracy in predicting weaning failure, in ready-to-wean mechanically ventilated chronic obstructive pulmonary disease (COPD) patients, needs to be evaluated.

Objective: Assessment of diaphragm using ultrasound during weaning from mechanical ventilation in COPD patients and to compare the new (D-RSBI) with traditional rapid shallow breathing index (RSBI).

Patients and Methods: A prospective observational study was carried out on mechanically ventilated COPD patients who were ready-to-wean. During spontaneous breathing trial (SBT), evaluation of the right hemi-diaphragmatic displacement and diaphragmatic thickness by using M-mode ultrasonography. Then calculation of D-RSBI (RR/DD) and RSBI (RR/tidal volume [VT]) were carried out simultaneously. Outcome of the weaning trials were recorded. Receiver operating characteristic curves were used to evaluate the diagnostic accuracy of D-RSBI and RSBI.

Results: A total of 104 patients with acute excerptions chronic obstructive pulmonary disease AECOPD who were ready to perform a SBT from mechanical ventilation. 86 (82.7%) were successfully liberated from mechanical ventilation and 18 patients (17.3%) had failure of weaning. The sensitivity and specificity of diaphragmatic displacement were 72.2% and 93.0% respectively. The sensitivity and specificity of RSBI were 77.8% and 70.9%. While the sensitivity and specificity of D-RSBI were 83.3% and 90.7% respectively.

Conclusion: D-RSBI (RR/DD) is superior than the traditional RSBI (RR/VT) in predicting weaning outcome patients with AECOPD.

Keywords: Diaphragmatic rapid shallow breathing, diaphragmatic displacement, COPD, spontaneous breathing trial, weaning.

INTRODUCTION

COPD is a major cause of chronic morbidity and mortality worldwide; many people have suffered from this disease for years and die prematurely because of it or its complications [1].

The diaphragm is the main respiratory muscle and contributes to 75% of the comfortable lung ventilation, with a journey of 1-2 cm. During forced breathing, the length of the trip is 7-11 cm, and is variable with individual characteristics and methods [2].

The evaluation of diaphragmatic mobility has been traditionally performed using fluoroscopy. In recent years, ultrasound has also become used to evaluate diaphragmatic mobility. It offers some advantages over fluoroscopy including the lack of ionizing radiation and the possibility of using at bedside of the patient. So ultrasonography has been shown to be a promising tool in the evaluation of the diaphragm function [3].

Mechanical ventilation (MV) is a life support measure for patients who cannot maintain adequate alveolar ventilation including COPD patients [4]. Discontinuing mechanical ventilation is a rapid and uneventful process for most patients, but for one of every four or five patients, the transition to spontaneous breathing is a prolonged process that can consume almost half of the total time on a ventilator [4].

Predicting extubation outcome and preventing extubation failure is, therefore an important task. Various weaning parameters have been suggested to be useful, e.g., minute ventilation (V_E), respiratory rate (RR), tidal volume (V_T), rapid shallow breathing index (respiratory rate divided by tidal volume, f/V_T), maximum inspiratory pressure (P_I max) and trans-diaphragmatic pressure (Pdi). However, the prediction rate of these parameters may not be satisfactory.

Evaluating the strength of the respiratory muscles becomes important, since the imbalance between respiratory demand and supply will lead to weaning failure through the development of respiratory muscles fatigue [5].

The rapid shallow breathing index (RSBI) (defined as the ratio of respiratory rate to tidal volume [RR/VT]) is one of the most widely used predictors of weaning outcome. However, unfortunately it has variable sensitivity and specificity. So, recently introduced the diaphragmatic RSBI (D-RSBI) by substituting VT with DD in the RSBI (ie, D-RSBI = RR/DD). This avoids masking the underlying diaphragmatic dysfunction caused by the contribution of the accessory muscles in

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generating VT that could impair the diagnostic accuracy of the RSBI [6].

AIM OF THE WORK

Assessment of diaphragm using ultrasound during weaning from mechanical ventilation in COPD patients and to compare the new D-RSBI with traditional rapid shallow breathing index (RSBI).

SUBJECT AND METHODS

Study design and subjects

A prospective observational study, carried out in the Respiratory ICU of the Abbasia Chest Hospitals, Alhussin University Hospital and Elsayed Galal Hospital during the period from November 2017 to October 2018. It included 104 patients with AECOPD who require MV. Patients with AECOPD were divided into two groups:

Group A: 86 patients mechanically ventilated COPD with weaning success.
Group B: 18 patients mechanically ventilated COPD with weaning failure.

The study was approved by the Faculty of Medicine, Al-Azhar University Ethics Committee. Written informed consent was obtained from all patients.

Inclusion Criteria

Chronic Obstructive Pulmonary Disease (COPD) patients with acute exacerbation.

Exclusion criteria

- Neuromuscular disease
- Use of muscle-paralyzing agents within 48 h before the study
- History or new detection of paralysis or paradoxical movement of a single hemi diaphragm on diaphragmatic ultrasonographic.
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Methods:

All studied patients were subjected to the following:

- Complete history taking, general and local chest clinical examination.
- Routine laboratory investigation examination including: CBC, Arterial blood gases (ABG), chest X ray and CT chest if needed

Patients were intubated and mechanically ventilated for more than 48 h were considered to be ready for SBT (ie, spontaneous ventilation through a pressure support) and met all of the following criteria:

1. Clinical improvement of the underlying cause for mechanical ventilation.
2. Improvement of respiratory failure.
3. Hemodynamic stability: Absence of active myocardial ischemia - Absence of clinically important hypotension (no vasopressor / low-dose vasopressors such as dopamine or dobutamine 5 μ/kg/min)
4. Intact ventilatory drive and patient has spontaneous breathing effort
5. Afebrile (temp. < 38C)
6. No significant respiratory acidosis
7. Adequate nutritional status (not hypo/hyper)
8. Stable metabolic status (electrolytes ; Ca, P, Mg)
9. Adequate Hb level (8-10 g/dl) / SVO_2 >65%
10. Adequate mentality (arousable, GCS>13, no continuous sedation)
11. Adequate oxygenation (ie, arterial oxygen saturation (SaO_2) 92% with inspiratory oxygen fraction (FiO_2) 0.5 with positive end expiratory pressure (PEEP) below 8 cmH_2O).
12. Adequate pulmonary function (ie, RR below 30 breaths/min with VT above 5 mL/kg ideal body weight (IBW) and no significant respiratory acidosis).

- Ultrasonographic scanning of the right hemi diaphragm after 30 min. from the beginning of the SBT. The patients were lying in the semi recumbent position, with the head of the bed elevated at an angle between 30° and 45°.
- Diaphragmatic movement was measured using superficial and deep US probe placed over one of the lower intercostal spaces in the right anterior axillary line with ultrasound. With the probe fixed on the chest wall during respiration, the ultrasound beam was directed to the hemi-diaphragmatic dome at an angle of not less than 70°. During inspiration, the normal diaphragm contracts and moves caudally toward the transducer; this is recorded as an upward motion of the M-mode tracing. The amplitude of excursion was measured on the vertical axis of the tracing from the baseline to the point of maximum height of inspiration on the graph. Four or three measurements were recorded and averaged. All measurements were performed during tidal breathing at 6–12 mL/kg, excluding smaller or deeper breaths. The whole US examination was accomplished in 5 min. Negative excursion was an indicator of paradoxical diaphragmatic movement.12 M-mode ultrasonography of the diaphragm of a patient with a conserved right hemi diaphragm function (DD = 16 mm) is shown in Figure (1). Diaphragmatic ultrasonography was performed for all patients by two independent operators to measure the DD. All patients' recordings were analyzed twice by both operators. All measurements were tested for intraobserver and interobserver reproducibility.

- Calculation of RSBI (RR/VT) and D-RSBI (RR/DD).
- Assessment of weaning outcome. A successful weaning trial was reported when patients were extubated and breathed spontaneously for more than 48 h.
- The reinstitution of mechanical ventilation during or at the end of the SBT, re-intubation within 48 h or the use of non-invasive ventilation (NIV) within 48 h of extubation were reported as a failed weaning trial.

Statistical analysis

Recorded data were analyzed using the statistical package for social sciences, version 20.0 (SPSS Inc., Chicago, Illinois, USA). Quantitative data were expressed as mean ± standard deviation (SD). Qualitative data were expressed as frequency and percentage.

The following tests were done:

- Independent-samples t-test of significance was used when comparing between two means.
- Chi-square (x^2) test of significance was used in order to compare proportions between two qualitative parameters.
- The confidence interval was set to 95% and the margin of error accepted was set to 5%. The p-value was considered significant as the following:
- Probability (P-value)
  - P-value < 0 .05 was considered significant.
  - P-value < 0.001 was considered as highly significant.
  - P-value >0.05 was considered insignificant.

RESULTS

Patient's demography: Table(1) showed no statistically significant difference between group A and B as regard sex, age, and smoking. Regarding patient's comorbidity, a significant statistical differences were present, as 32 patients (37.2%) from **group A** had successful weaning with co-morbidities (from 86 pt.) while 16 patients (88.9%) from **group B** had weaning failure with co-morbidities (from 18 pt).

Table (1): Patients characteristics

Demographic data	All patients	Group (A) Weaning success	Group (B) Weaning failure	Test	P-value (Sig.)
Number (%)	104 (100%)	86 (82.7%)	18 (17.3%)		
Age (years)					
Mean ± SD	62.6 ± 5.9	63.0 ± 6.0	60.7 ± 4.9	1.344 •	0.179(NS)
Median (Range)	63 (48 – 75)	63 (48 – 75)	62 (51 – 67)		
Gender					
Male	90 (86.5%)	74 (89%)	16 (88.9%)	0.103 ‡F	1.00(NS)
Female	14 (13.5%)	12 (14%)	2 (11.1%)		
Comorbidities					
Patients with comorbidities	48 (46.2%)	32 (37.2%)	16 (88.9%)	15.996 ‡	<0.001(HS)
HTN	32 (30.8%)	22 (25.6%)	10 (55.6%)	6.278 ‡	0.012(S)
DM	24 (23.1%)	14 (16.3%)	10 (55.6%)	12.935 ‡F	0.001(S)
IHD	18 (17.3%)	12 (14%)	6 (33.3%)	3.906 ‡F	0.080(NS)
AF	8 (7.7%)	2 (2.3%)	6 (33.3%)	20.155 ‡F	<0.001(HS)
Smoking					
Non-smoker	14 (13.5%)	12 (14%)	2 (11.1%)	0.115 ‡	0.944(NS)
Ex-smoker	12 (11.5%)	10 (11.6%)	2 (11.1%)		
Heavy smoker	78 (75%)	64 (74.4%)	14 (77.8%)		

* Independent samples Student's t-test.
• Mann Whitney U test.
‡Chi-square test.
‡F Fisher's Exact test.
P < 0.05 is significant.
Sig.: significance.

Weaning parameters: Table (2) showed highly statistically significant difference between both groups where FiO_2 in weaning success was 42.1 ± 4.1 and in weaning failure group was 50.0 ± 6.9, O2, saturation in patients with successful weaning was 93.5 ± 1.4 in comparison with 91.7 ± 1.1 in failed group. Finally, tidal volume in successful patients was 385 ± 29 in comparison with 338 ± 37 in failed group.

Table (2): Parameters of weaning

Parameters of weaning	All patients	Group (A) Weaning success	Group (B) Weaning failure	Test	P-value (Sig.)
Number (%)	104 (100%)	86 (82.7%)	18 (17.3%)		
Tidal volume (mL/inspiration)					
Mean ± SD	377 ± 35	385 ± 29	338 ± 37	4.315 •	<0.001(HS)
Median (Range)	383.5 (299 – 450)	387 (312 – 450)	355 (299 – 400)		
FiO2 (%)					
Mean ± SD	43.5 ± 5.5	42.1 ± 4.1	50.0 ± 6.9	-5.078 •	<0.001(HS)
Median (Range)	40 (40 – 60)	40 (40 – 50)	50 (40 – 60)		
Respiratory rate (breath/min)					
Mean ± SD	14.8 ± 0.9	14.7 ± 0.9	15.1 ± 1.1	-1.296 •	0.195(NS)
Median (Range)	14 (14 – 17)	14 (14 – 16)	15 (14 – 17)		
O2 (%)					
Mean ± SD	93.2 ± 1.6	93.5 ± 1.4	91.7 ± 1.1	4.784 •	<0.001(HS)
Median (Range)	93 (90 – 98)	93 (91 – 98)	92 (90 – 93)		

• Mann Whitney U test.
P < 0.05 is significant.
Sig.: significance.

Predictors of failed weaning and its accuracy

In successful group, DRSBI was 1.11 ± 0.34 compared to failed weaning group B (2.24 ± 0.69) with statistically highly significant difference between both groups. In addition, successful group A had lower RSBI (67.4 ± 11.7) compared to failed weaning group B (85.6 ± 16.7) with statistically highly significant difference between both groups. Diaphragmatic displacement (DD) was higher in group A (23.1 ± 4.2) compared to group B (16.0 ± 5.4) with statistically highly significant difference between both groups. Finally, group A had higher diaphragmatic thickening (%), which was 23.2 ± 3.9 compared to failed weaning group B, which was (17.4 ± 6.4) with statistically highly significant difference between both groups.

Table (3): Patient's D-RSBI, RSBI, DD and diaphragmatic thickening predictors, weaning predictors among studied patient.

SBT parameters	All patients	Group (A) Weaning success	Group (B) Weaning failure	Test	P-value (Sig.)
Number (%)	104 (100%)	86 (82.7%)	18 (17.3%)		
D-RSBI (breaths/min/mm)					
Mean ± SD	1.31 ± 0.60	1.11 ± 0.34	2.24 ± 0.69	-5.104 •	<0.001(HS)
Median (Range)	1.01 (0.91 – 3.4)	1.0 (0.91 – 2.52)	2.28 (0.95 – 3.4)		
RSBI (breaths/min/L)					
Mean ± SD	70.5 ± 14.5	67.4 ± 11.7	85.6 ± 16.7	-3.824 •	<0.001(HS)
Median (Range)	65.9 (48.8 – 102.6)	64 (48.8 – 102.6)	93.6 (55.4 – 102.6)		
Diaphragmatic displacement (mm)					
Mean ± SD	21.9 ± 5.2	23.1 ± 4.2	16.0 ± 5.4	4.233 •	<0.001(HS)
Median (Range)	24.0 (9.0 – 28.1)	24.3 (9.3 – 28.1)	13.5 (9.0 – 25.5)		
Diaphragmatic thickening (%)					
Mean ± SD	22.2 ± 4.9	23.2 ± 3.9	17.4 ± 6.4	3.621 •	<0.001(HS)
Median (Range)	24 (9 – 27)	24 (10 – 27)	18 (9 – 26)		

• Mann Whitney U test.
P < 0.05 is significant.
Sig.: significance.

Table (4) and figure (1) showed highly statistically significant accuracy of D-RSBI, RSBI, DD and RR after SBT in predicting weaning failure by using ROC curve. DRSBI is highly sensitive and specific more than other indices such as RSBI, DD and RR after SBT in predicting weaning failure.

Table (4): Sensitivity, Specify, NPV and PPV according to weaning predictors.

Cut-off values	SN % (95% CI)	SP % (95% CI)	PPV % (95% CI)	NPV % (95% CI)	Accuracy % (95% CI)	AUROC (95% CI)	P-value (Sig.)
D-RSBI ≥ 1.42	83.3% (58.6 – 96.4)	90.7% (82.5 – 95.9)	65.2% (42.7 – 83.6)	96.3% (89.6 – 99.2)	89.4% (81.9 – 94.6)	0.882 (0.718 – 0.954)	<0.001 (HS)
RSBI ≥ 69.7	77.8% (52.4 – 93.6)	70.9% (60.1 – 80.2)	35.9% (21.2 – 52.8)	93.9% (85.0 – 98.3)	72.1% (62.5 – 80.5)	0.788 (0.599 – 0.893)	<0.001 (HS)
DD ≤ 16.6	72.2% (46.5 – 90.3)	93.0% (85.4 – 97.4)	68.4% (43.5 – 87.4)	94.1% (86.8 – 98.1)	89.4% (81.7 – 94.6)	0.817 (0.660 – 0.906)	<0.001 (HS)
RR ≥ 24	77.8% (52.4 – 93.6)	27.9% (18.8 – 38.6)	18.4% (10.5 – 29.0)	85.7% (67.3 – 96.0)	36.5% (27.3 – 46.6)	0.687 (0.453 – 0.832)	0.049 (S)

ROC curve: Receiver Operating Characteristic curve.
SN: Sensitivity.
SP: Specificity.
PPV: Positive Predictive Value.
NPV: Negative Predictive Value.
AUROC: Area Under Receiver Operating Characteristic curve.
95%CI: 95% Confidence Interval.
p< 0.05 is significant.
Sig.: significance.

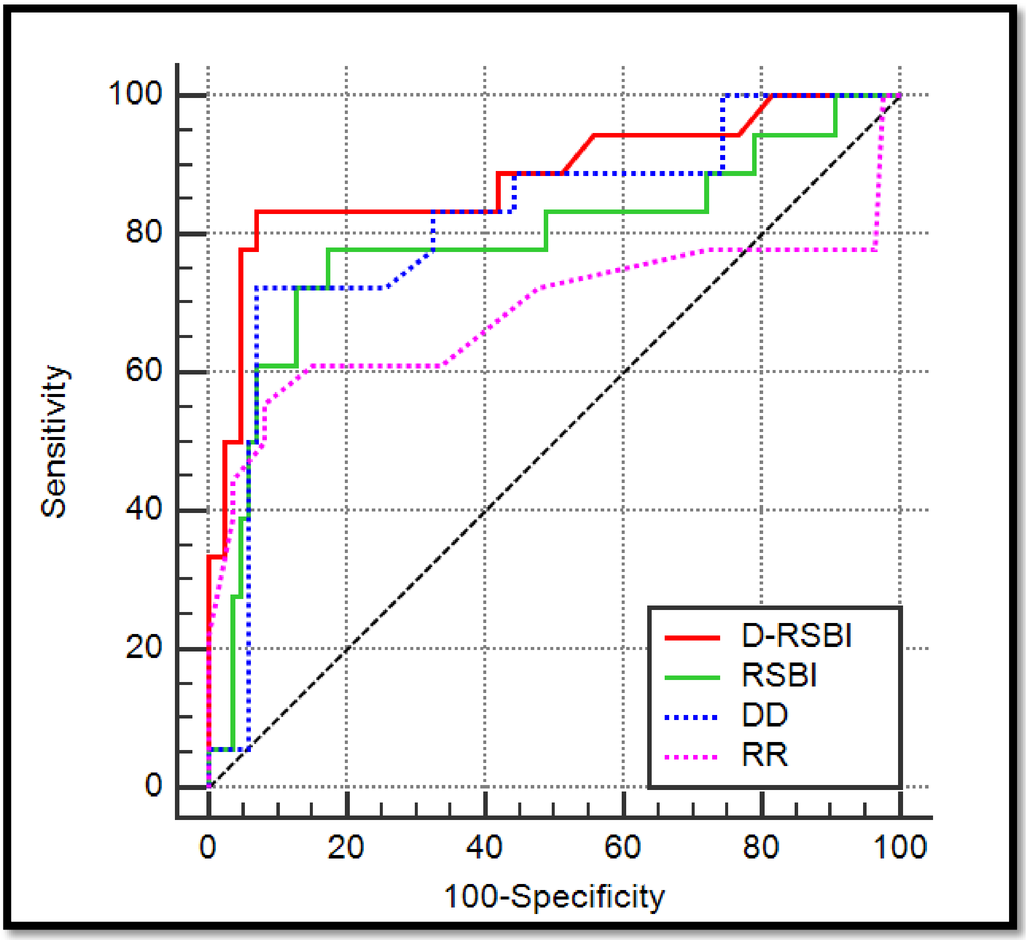

Figure (1): Receiver operating characteristic (ROC) curve for diaphragmatic displacement (DD), diaphragmatic rapid shallow breathing index (D-RSBI), respiratory rate (RR) and traditional rapid shallow breathing index (RSBI).

The AUROC for D-RSBI was significantly different from the one for RSBI (0.89 versus 0.72; P = 0.001).

DISCUSSION

In the current study, table (1) showed 90 pt were males and 14 pt were female with a mean age of 63.0 ± 6.0 years old in group A, and 60.7 ± 4.9 years old in group B. There was no significant statistical difference between the patients with successful and failed weaning groups as regard the age, sex and smoking. This is in agreement with many studies like that of **Spadaro *et al.*** [6]**, Abbas *et al.*** [7] and **Makhlof *et al.*** [8].

As regard number of co-morbid disease in the current study, 48 patients had co-morbid diseases in which 32 patients had hypertension (22 patients had successful weaning and 10 patients had weaning failure). 24 patients had diabetes mellitus (14 patient had successful weaning and 10 patients had weaning failure). 18 patients had ischemic heart disease (12 patients had successful weaning and 6 patients had weaning failure). Besides, 8 patients had chronic atrial fibrillation (2 patients had successful weaning and 6 patients had weaning failure). This revealed that, patients with multiple co-morbid diseases were associated with high rate of weaning failure, there was significant statistical difference between the patient groups as regards the comorbidity (HTN, IHD,AF and DM). This was in agreement with **Spadaro *et al.*** [6] **and Ongel *et al.*** [9].

Ongel *et al.* [9] studied the effect of COPD co morbidities in the ICU outcome in 1013 patients in the period from January 2008 to December 2012. The study reported that patients with multiple co morbidities especially cardiac co-morbidities had a higher risk of mechanical ventilation and failure of weaning, with higher rates of mortality. Also, our study is in accordance with that of **El Hoffy and Khamis** [10] where in their study, ten patients had diabetes mellitus (seven of them had successful weaning and three patients had weaning failure), twenty patients had hypertension (three of them had successful weaning and seven had weaning failure), twelve patients had coronary artery diseases (nine of them had successful weaning and three patients had weaning failure) and six patients had congestive heart failure (four of them had successful weaning and two patients had weaning failure), with higher failure rates among patients with multiple co-morbid diseases. The high prevalence of COPD among male patients was attributed to the high rate of smoking and the occupational exposure.

In our study, the mean value of rapid shallow breathing index (RSBI) was 67.4 ± 11.7 in the group of patients of successful weaning and 85.6 ± 16.7 in the group of patients of failed weaning, with sensitivity 77.8 %, specificity 70.9 % and accuracy 72.1 % using cutoff value < 105, with statistically significant difference between both groups. RSBI was high in the group of failed weaning as the patients had rapid respiratory rate and low tidal volume in contrast to the patients in the group of successful weaning. This is in agreement with the study carried out by **Abbas *et al.*** [7] where a total of 50 AECOPD patients requiring mechanical ventilation for more than 48 h who were ready to perform a SBT were included. Of these, 37 (74%) were successfully liberated from mechanical ventilation. Among the 13 patients who failed the weaning trial, 8 (62%) failed the SBT and reconnected to the ventilator, 2 (15%) were reintubated within 48 h of extubation and 3 (23%) required NIV support within 48 h of extubation. The areas under the ROC curves for D-RSBI and RSBI were 0.97 (p < 0.001) and 0.67 (p < 0.06) respectively.

Regarding assessment of the diaphragmatic displacement, the mean value in **group B** (failure of weaning), was 16.0 ± 5.4 mm, which was higher than the mean value in **group A** (success of weaning), which was 23.1 ± 4.2mm, with statistically significant difference between both groups. This was explained by the respiratory muscle dysfunction in the mechanically ventilated patients, with sensitivity 72.2%, specificity 93.0% and accuracy of 89.4% using cutoff value 16.6 mm.

In the current study, the mean value of rspiratory rate (RR) in the group of successful weaning was 14.7 ± 0.9, which is lower than the mean value in the group of failed weaning (15.1 ± 1.1). There was statistically significant difference between both groups, with sensitivity 77.8%, specificity 27.9% and accuracy of 36.5%, using cutoff value ≥ 24. There is in agreement with study of **Spadaro *et al.*** [6] where the mean value of respiratory rate (RR) in the patients with successful weaning was 18 ± 5, which was lower than the mean value in the patients with failed weaning (24 ± 7). There was statistically significant difference between both groups with sensitivity 64.7%, specificity 76.5% and accuracy of 76% using cut off value >20. Also, it is in agreement with study of **Abbas *et al.*** [7] where the mean value of respiratory rate (RR) in the patients with successful weaning was 23.64 ± 6.48, which was lower than the mean value in the patients with failed weaning (29.38 ± 11.27). There was statistically significant difference between both groups, with sensitivity 100%, specificity 29.7% and accuracy of 48% using cut off value >19.

In the current study, the mean value of tidal volume in the group of successful weaning was 385 ± 29 ml, which was higher than the mean value in the group of failed weaning (338 ± 37 ml) with statistically significant difference between both groups. This is in agreement with **Makhlouf *et al.*** [8] study where the mean value of tidal volume in the group of successful weaning was 420 ml, which

was also higher than the mean value in the group of failed weaning (343 ml) with statistically significant difference between both groups. **El Hoffy and Khamis** [10] reported that the mean value of tidal volume in the group of successful weaning was 375 ml, which was also higher than the mean value in the group of failed weaning (278 ml) with statistically significant difference between both groups. This is also in agreement with **Jiang *et al.*** [11] where the mean value of tidal volume in the group of successful weaning was 382 ml, which was higher than the mean value in the group of failed weaning (286 ml) with statistically significant difference between both groups. **Mabrouk *et al.*** [12]**,** although the mean value of tidal volume in the group of successful weaning was 427 ml, which is higher than the mean value in the group of failed weaning (385 ml) but there was no statistically significant difference between both groups. This may be explained as the mechanically ventilated patients with non-respiratory causes were included in the study, also the weaning methods from mechanical ventilation were different in each group and the number of patients was different.

Regarding assessment of the diaphragmatic rabid shallow breathing index (DRSBI), in **group A**, the mean value in the patients with successful weaning was 1.11 ± 0.34, which was lower than the mean value in the patients with failed weaning (2.24 ± 0.69). There was statistically significant difference between both groups with sensitivity 83.3%, specificity 90.7% and accuracy of 89.4% using cut off value ≥ 1.42. There is agreement with study of **Spadaro *et al.*** [6] where the mean value of DRSBI in the patients with successful weaning was 1.2, which was lower than the mean value in the patients with failed weaning (2.7). There was statistically significant difference between both groups, with sensitivity 94.1%, specificity 64.7% and accuracy of 89% using cut off value >1.3. Besides, there is agreement with the study of **Abbas *et al.*** [7] who reported that the mean value of DRSBI in the patients with successful weaning was 1.43 ± 0.32, which was lower than the mean value in the patients with failed weaning (3.27 ± 0.84). There was statistically significant difference between both groups with sensitivity 84.6%, specificity 100% and accuracy of 96% using cut off value >1.9.

Regarding assessment of the rabid shallow breathing index (RSBI), the mean value in the group B (failed weaning), was 85.6 ± 16.7, which was higher than the mean value in group A (67.4 ± 11.7). There was statistically significant difference between both groups with sensitivity 77.8%, specificity 70.9% and accuracy of 72.1%using cut off value ≥ 69. This was explained by the respiratory muscle dysfunction in the mechanically ventilated patients.

CONCLUSION

We conclude that DD, when combined with RR in an index that we named D-RSBI (RR/DD), becomes more accurate than the traditional RSBI (RR/VT) in predicting the weaning outcome. A cut-off of 1.3 is associated with the best sensitivity and specificity. Our results confirm the importance of rapid and shallow breathing as a global index of weaning-induced patient distress.

The sensitivity and specificity of RSBI were 77.8% and 70.9%. While the sensitivity and specificity of D-RSBI were 83.3% and 90.7% respectively.

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